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COMPUTER-ACQUIRED PERFORMANCE DATA FROM A PHYSICALLY VAPOR-DEPOSITED-TUNGSTEN, NIOBIUM PLANAR DIODE

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Cleveland, Ohio 44135

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16. Abstract

Performance data from a physically vapor-deposited-tungsten, niobium thermionic converter are presented. The planar converter has a guard-ringed collector and a fixed space of 0.254 mm (10 mils). The data were acquired by means of a computer, and are available on microfiche as individual or composite, parametric J, V curves. The parameters are the temperatures of the emitter, T_E, collector, T_C, and cesium reservoir, T_R. The composite plots have constant T_E and varying T_C or T_R, or both. The envelope and composite plots having constant T_E are presented. The diode was tested at temperature increments between 1500 and 2000 K for the emitter, 765 and 1057 K for the collector, and 521 and 652 K for the reservoir. In all, 432 individual current, voltage curves were obtained.

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COMPUTER-ACQUIRED PERFORMANCE DATA FROM A PHYSICALLY VAPOR-DEPOSITED-TUNGSTEN, NIOBIUM PLANAR DIODE

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SUMMARY

A fixed-spaced planar diode with a guarded collector has been performance-mapped in a multistation facility which is connected to a centralized computer data acquisition system. The physically vapor-deposited tungsten emitter was separated from the niobium collector by 0.254 millimeter (10 mils). The use of the computer system allowed off-design as well as on-design conditions to be observed. Emitter temperatures (T_E) from 1500 to 2000 K were tested. Collector temperatures (T_C) were varied from 765 to 1057 K, and cesium reservoir temperatures (T_R) were varied from 521 to 652 K. The composite plots and their envelopes, with constant T_E and varying T_C and T_R are presented. The collection of the 432 current, voltage curves was achieved by sweeping the diode over a period of approximately 10 milliseconds with a variable transistorized load controlled by the central digital computer.

INTRODUCTION

Lower operating temperatures and the absence of radiation and reactor compatibility requirements associated with out-of-core thermionics allow the use of electrode materials that are prohibited by in-core operations. Because of this new freedom of choice in materials and operating temperatures, a program has been initiated to map the performance of various planar electrode combinations at off-design as well as on-design conditions. Used for part of this program are six 0.254 millimeter (10 mil) spaced planar converters with guarded niobium or molybdenum collectors and either rhenium or tungsten emitters (ref. 1). The results obtained for the electrode combination of a physically vapor-deposited tungsten emitter and a niobium collector are reported herein. Similar results for an etched rhenium emitter and niobium collector are presented in references 2 and 3.

Data were recorded by means of a computer system as described in reference 4. This system allows the rapid application of a variable transistorized load and makes possible the testing at off-design as well as on-design conditions. The data are presented on composite J, V plots for constant emitter temperatures (T_E) and varying the collector and cesium reservoir temperatures (T_C and T_R). Data were gathered for emitter temperatures from 1500 to 2000 K. The collector was varied from 765 to 1057 K, and the reservoir from 521 to 652 K.

TEST FACILITY

Test Stations

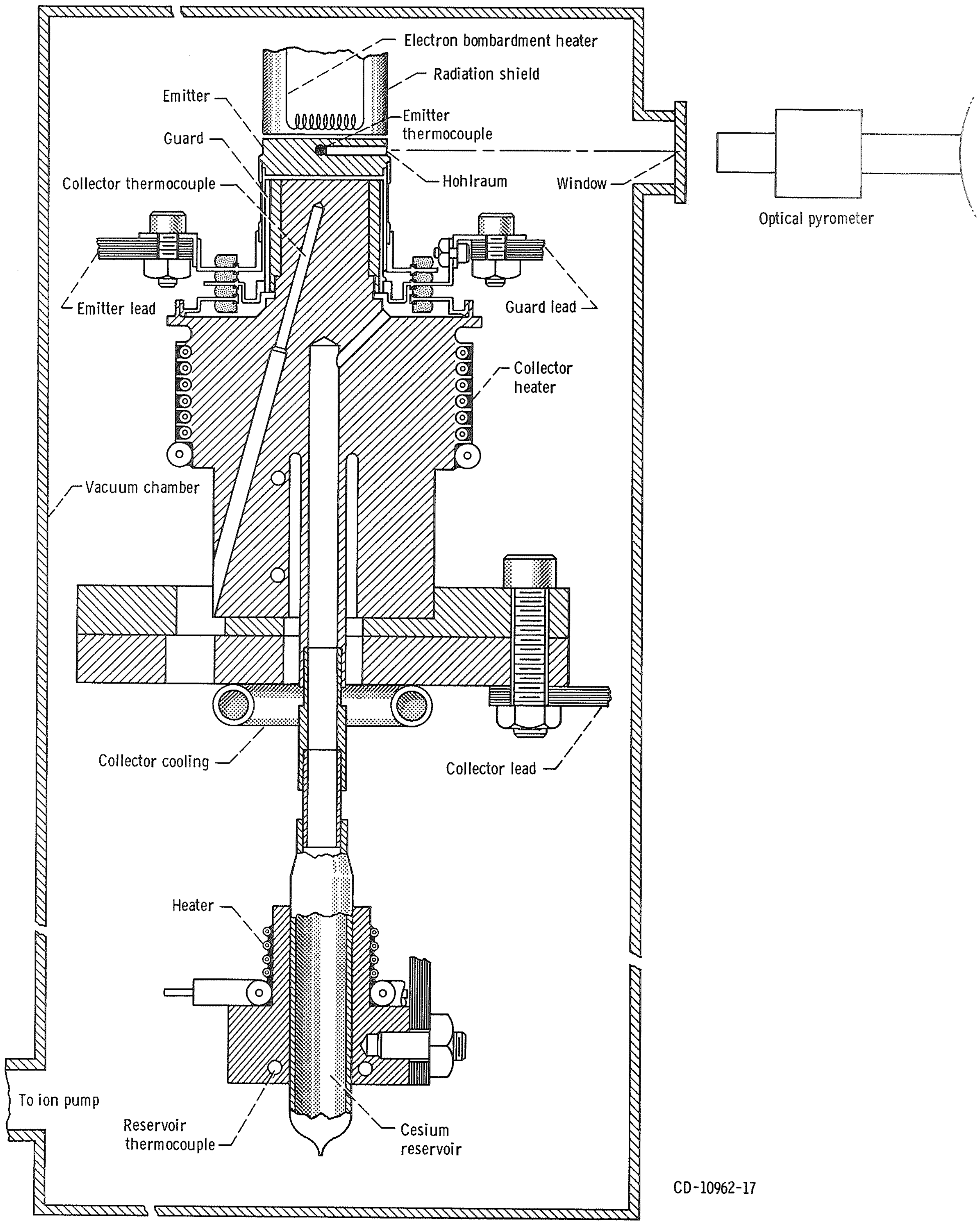
The converters (see illustration) were fabricated, then filled with cesium by the contractor.[1] They may be mounted in any of six vacuum test stations which have a central instrumentation control panel. Each station has its own set of emitter (electron-bombardment), collector, and cesium-reservoir heat supplies. Thermal balance of the collector and reservoir is achieved through conduction to water lines. Typical operating pressures under heat load for these systems are less than 5×10^{-7} torr after a thorough bake-out.

Instrumentation

The current developed in the converter was measured by the voltage drop across either a 0.01- or 0.1-ohm precision shunt. The emitter, collector potential difference was measured at the external shroud of the converter. No corrections were made for the voltage drop in the emitter support shroud since it is approximately 1.8 millivolts per ampere per square centimeter of electrode surface. The area used in determining the current density was that of the collector, 1.55 square centimeter. The guard-ring was electrically connected to the circuit on the opposite side of the shunt from the collector.

The collector and cesium reservoir temperatures were sensed by sheathed Chromel, Alumel thermocouples embedded in their respective converter structures. The couples were continuous and were brought through the vacuum wall of the test station into a common ambient cold junction zone. The temperature of the ambient zone was sensed by a Chromel, Alumel couple that was referenced electronically to 273 K. Two couples were inserted at each location. The cesium reservoir couples were located in

[1]Thermo Electron Engineering Corp., Waltham, Massachusetts.



Converter configuration.

the copper block surrounding the copper tube containing the cesium (see illustration). The collector couples were inserted to within 3.05 millimeters (125 mils) of the collector surface. The standard Chromel, Alumel calibration for all four couples was verified by an in situ comparison against a reference Chromel, Alumel couple.

The emitter temperature was sensed by a sheathed high temperature couple of tungsten, 5-percent-rhenium versus tungsten, 26-percent-rhenium. The couple was inserted to a depth of 6.35 millimeters (250 mils) from the emitter substrate edge and 3.3 millimeters (130 mils) from the active face of the emitter (see illustration). Compensating lead wires were attached to the couple on the interior of the test chamber and were brought out to a room temperature cold junction. An in situ calibration of the high temperature couple was done against a black body cavity (length to diameter ratio of five) in the edge of the emitter. Observations of the black body cavity were made through a window in the test station with a disappearing filament optical pyrometer. The optical path and pyrometer were calibrated against an NBS tungsten strip lamp. The maximum uncertainty associated with the observed temperature is approximately $\pm 10^{\circ}$. This estimate takes into account the accuracy of the NBS calibration, the reversal capabilities of the optical pyrometer and observer, the effect of the approximate black body cavity, and the goodness of fit of the linear calibration curve obtained for the couple. The temperature difference between the emitter thermocouple location and the active face of the tungsten emitter is considered negligible based on a one-dimensional heat balance of the radiation across the interelectrode gap and the heat conducted through the emitter. This model neglects any heat flow through the emitter-support shroud since the electron-bombardment filament was designed to nullify this heat path. Electron cooling effects on the surface temperature are negligible since the period over which the load is applied is very short (ref. 4). The contribution of gaseous conduction is negligible.

TEST PROCEDURE

The computer-controlled data acquisition system is programmed to trigger the variable load at up to six different emitter temperatures during a given test interval of approximately 20 seconds. (The computer program was written by E. J. Manista and C. F. Kadow of the Lewis Research Center.) This is accomplished with the system by sensing the emitter temperature and, upon its reaching a predetermined value, triggering the load. The actual temperature levels at which the system is triggered are introduced into the program by the operator as independent input data. The data recording program, synchronized with the variable load, samples the J, V characteristics of the converter at each temperature level 90 times during the load application of approximately 10 milliseconds duration. Sample and hold amplifiers coordinate in time the collector current and collector, emitter potential difference.

The converter was mapped by fixing the temperatures of the cesium reservoir and the collector and heating the emitter to the predetermined levels by changing the input power to the emitter. By changing the programmed trigger levels, 11 different emitter temperatures between 1500 and 2000 K were observed in 50 K increments. The collector temperature was then changed, and the preceding procedure was repeated. Four different collector temperatures between 765 and 1057 K at approximately 100 K increments were observed. The cesium reservoir temperature was then changed, and the procedure was again repeated. Six different reservoir temperatures between 521 and 652 K at 25 K increments were established. At least one sweep or pulse of the variable transistorized load was made at each one of the reservoir-, collector-, emitter-temperature combinations. All temperatures were recorded at the end of each J, V sweep. Between sweeps, these analog temperatures were converted by the computer to their values in degrees Kelvin and were printed out for use by the operator in setting conditions.

DATA PRESENTATION

Since the local computer can store and recall only a limited number of successive sweeps, the data are transmitted to the Lewis Central Computing Center for storage on magnetic tape and some engineering calculations. The data are sorted into groups of common emitter temperatures and are displayed in order of ascending T_E on microfilm output. Both J, V and P, V (power density) curves are displayed on this output, with the J and P scales being determined by the maximum J and P of each sweep. Two additional sorts are done by the Central Computer. The data are grouped by common emitter and collector temperatures and varying reservoir temperatures; and they are grouped by common emitter and reservoir temperatures and varying collector temperatures. The computer plots all the sorted J, V data on composite parametric plots and displays them on the microfilm output. The current density scales on these plots are all common and limited to a maximum J of 30 amperes per square centimeter.

Table I lists the temperature conditions for the composite plots presented in figures 1 to 11. (See back of report.) These figures show all J, V data obtained at emitter temperatures from 1500 to 2000 K. The envelope of the points of these figures represents the optimum performance of the converter for the conditions at which it was operated. All of the envelopes for the different T_E's are plotted in figure 12. Although the last figure yields all of the information contained in figures 1 to 11, the individual computer-processed plots are presented to illustrate the density of data required to adequately establish the optimum envelope curves.

In all, 432 individual J, V plots were generated in developing these envelopes. These are available on request from the author in microfiche form. Also available on microfiche are composite J, V plots at constant T_E and constant T_C or T_R. Table II lists the temperature conditions included on these computer-processed plots.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, April 29, 1971,
120-27.

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2. Lancashire, R. B.: Computer-Acquired Performance Map of an Etched-Rhenium, Niobium Planar Diode. Presented at the IEEE Thermionic Conversion Specialist Conference, Miami, Fla., Oct. 1970.
3. Lancashire, R. B.: Computer-Acquired Performance Data From an Etched-Rhenium, Niobium Thermionic Converter. NASA TM X-2262, 1971.
4. Breitwieser, R.; Manista, E. J.; and Smith, A. L.: Computerized Performance Mapping of a Thermionic Converter with Oriented Tungsten Electrodes. Presented at the IEEE Thermionic Conversion Specialist Conference, Carmel, Calif., Oct. 1969.

TABLE I. - INDEX OF PERFORMANCE FIGURES PRESENTED

Figure number	Emitter temperature, T_E, K	Collector temperature range, T_C, K	Cesium reservoir temperature range, T_R, K	Number of J, V curves
1	1500	770 to 1047	522 to 651	24
2	1550	772 to 1047	522 to 651	24
3	1600	765 to 1048	522 to 652	48
4	1650	771 to 1050	521 to 651	24
5	1700	767 to 1049	522 to 651	47
6	1750	767 to 1050	523 to 651	
7	1800	767 to 1049		
8	1850	768 to 1052		
9	1900	769 to 1055		
10	1950	773 to 1057		24
11	2000	771 to 1055		47
12	All	Envelopes	Envelopes	--

TABLE II. - LIST OF COMPOSITE PLOTS AVAILABLE ON MICROFICHE

Emitter temperature, T_E, K	Collector temperature range, T_C, K	Cesium reservoir temperature range, T_R, K	Emitter temperature, T_E, K	Collector temperature range, T_C, K	Cesium reservoir temperature range, T_R, K	Emitter temperature, T_E, K	Collector temperature range, T_C, K	Cesium reservoir temperature range, T_R, K
1500	775	522 to 648	1700	775	522 to 648	1900	775	523 to 649
	850	523 to 649		850	523 to 649		850	523 to 649
	950	524 to 650		950	524 to 650		950	525 to 650
	1050	526 to 651		1050	525 to 651		1050	526 to 651
	770 to 1040	525		772 to 1047	525		769 to 1046	525
	771 to 1041	555		768 to 1044	555		769 to 1051	555
	772 to 947	575		771 to 1043	575		777 to 1047	575
	778 to 1042	600		767 to 1049	600		769 to 1047	600
	770 to 1044	625		773 to 1045	625		776 to 1045	625
	772 to 1043	650		774 to 1045	650		774 to 1050	650
1550	775	522 to 648	1750	775	523 to 648	1950	775	523 to 649
	850	523 to 649		850	523 to 649		850	523 to 649
	950	524 to 650		950	524 to 650		950	525 to 650
	1050	526 to 651		1050	526 to 651		1050	526 to 651
	772 to 1043	525		770 to 1046	525		773 to 1046	525
	773 to 1047	555		767 to 1045	555		774 to 1050	555
	774 to 946	575		770 to 1043	575		777 to 953	575
	778 to 1041	600		768 to 1050	600		775 to 1048	600
	774 to 1045	625		774 to 1044	625		778 to 1045	625
	775 to 1043	650		775 to 1045	650		780 to 1049	650
1600	775	522 to 649	1800	775	523 to 649	2000	775	523 to 648
	850	523 to 649		850	523 to 650		850	523 to 650
	950	525 to 650		950	525 to 650		950	524 to 650
	1050	526 to 652		1050	526 to 651		1050	526 to 651
	768 to 1047	525		770 to 1046	525		771 to 1049	525
	770 to 1047	555		767 to 1049	555		773 to 1049	555
	770 to 948	575		773 to 1044	575		775 to 955	575
	765 to 1048	600		769 to 1049	600		771 to 1054	600
	772 to 1045	625		775 to 1045	625		774 to 1045	625
	770 to 1044	650		775 to 1049	650		774 to 1052	650
1650	775	521 to 648	1850	775	523 to 648			
	850	523 to 649		850	524 to 649			
	950	524 to 650		950	525 to 651			
	1050	525 to 651		1050	525 to 651			
	771 to 1047	525		770 to 1046	525			
	771 to 1045	555		768 to 1052	555			
	777 to 951	575		775 to 1045	575			
	782 to 1046	600		769 to 1046	600			
	773 to 1046	625		776 to 1045	625			
	777 to 1044	650		774 to 1052	650			

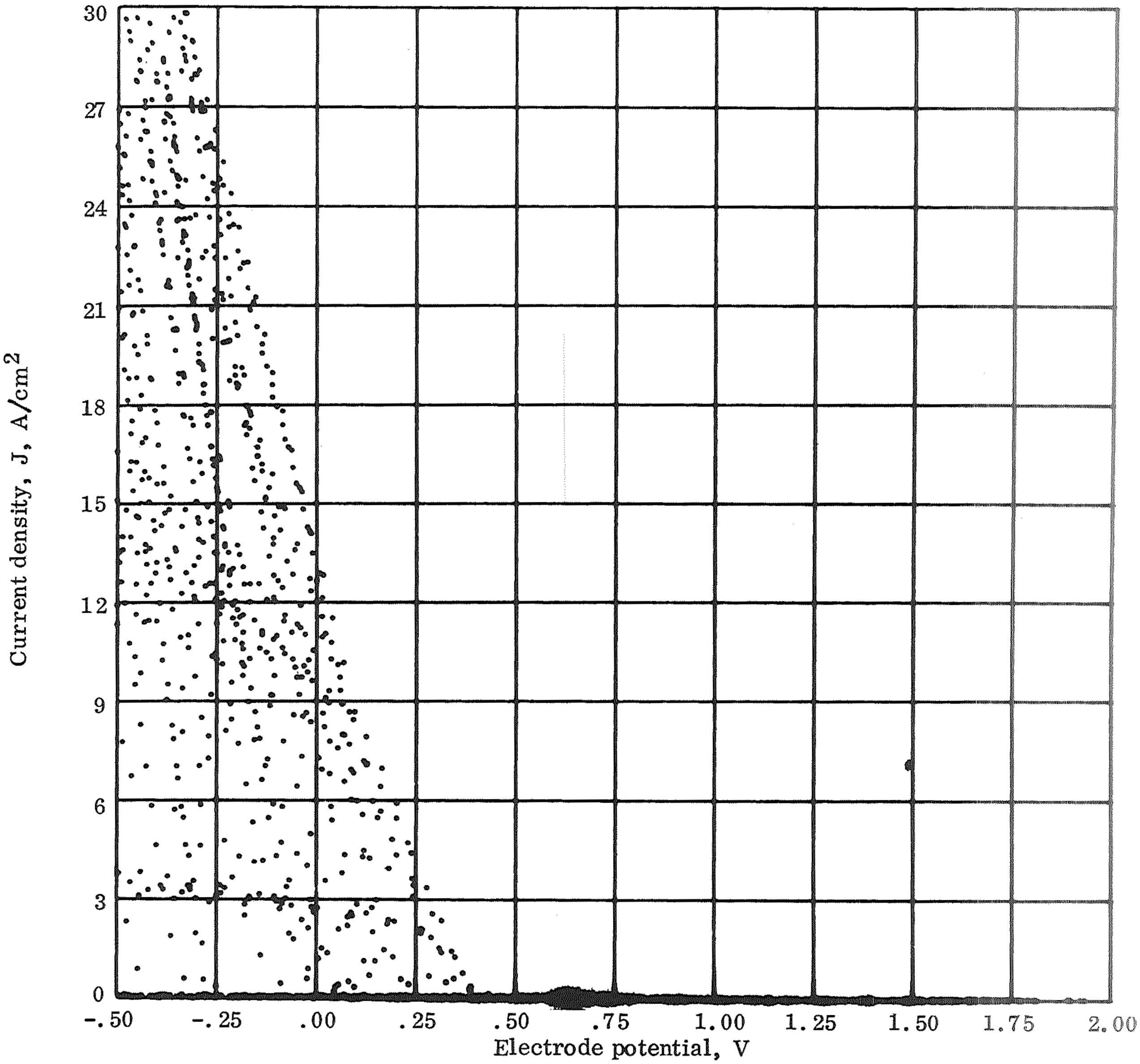

Figure 1. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1500 K. Collector temperature, 770 K to 1047 K; cesium reservoir temperature, 522 K to 651 K; interelectrode space, 0.254 mm (10 mils).

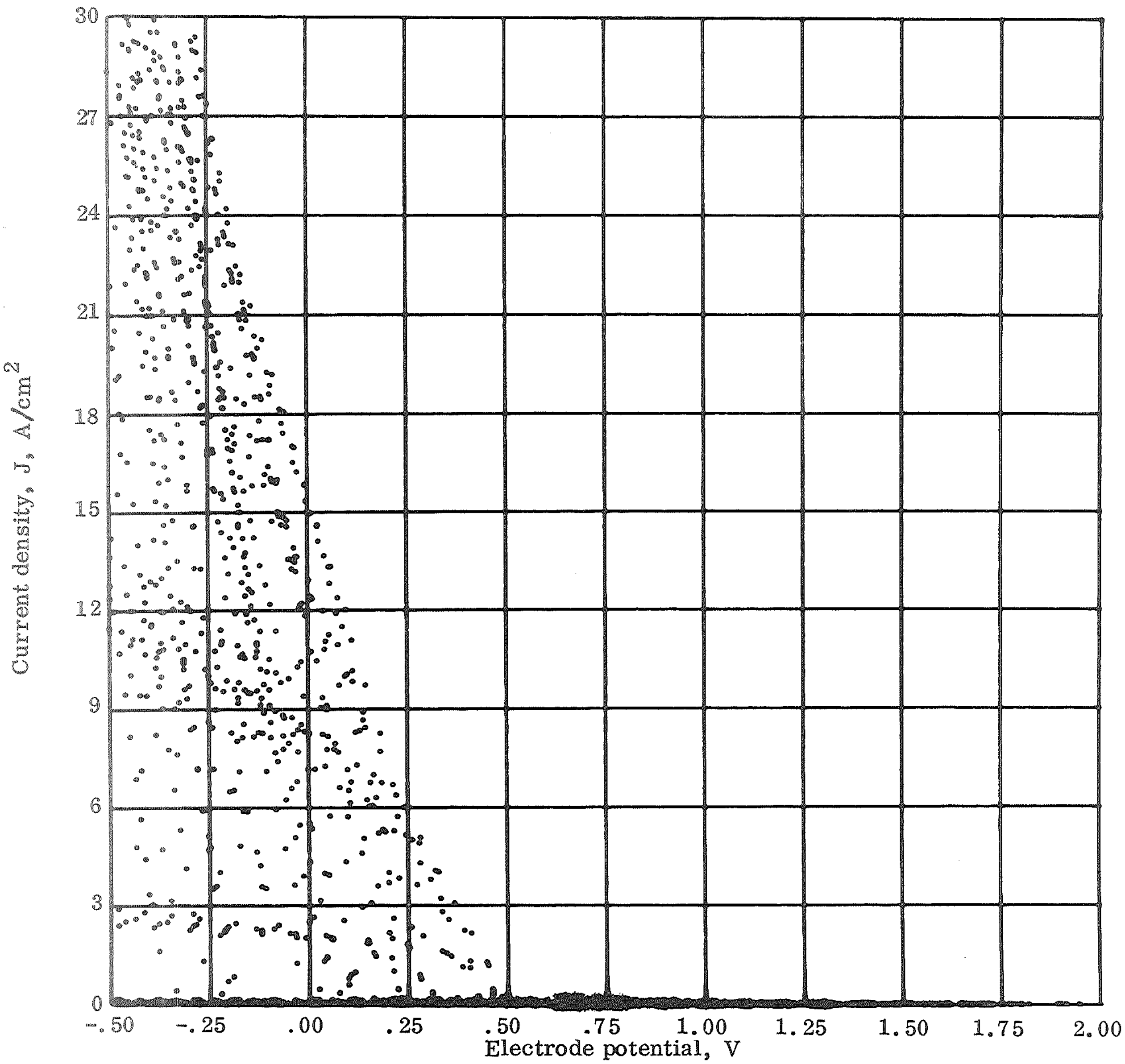

Figure 2. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1550 K. Collector temperature, 772 K to 1047 K; cesium reservoir temperature, 522 K to 651 K; interelectrode space, 0.254 mm (10 mils).

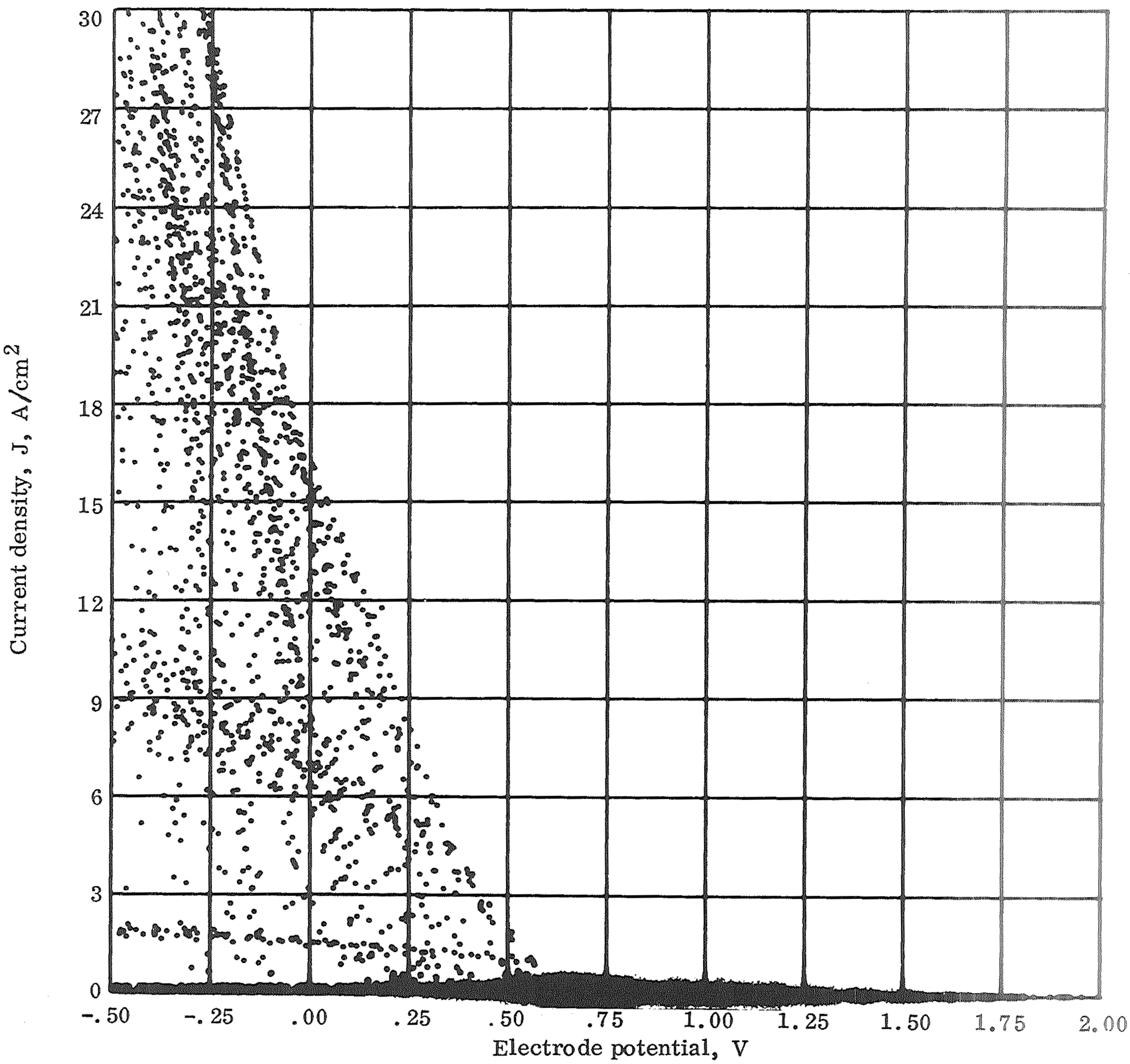

Figure 3. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1600 K. Collector temperature, 765 K to 1048 K; cesium reservoir temperature, 522 K to 652 K; interelectrode space, 0.254 mm (10 mils).

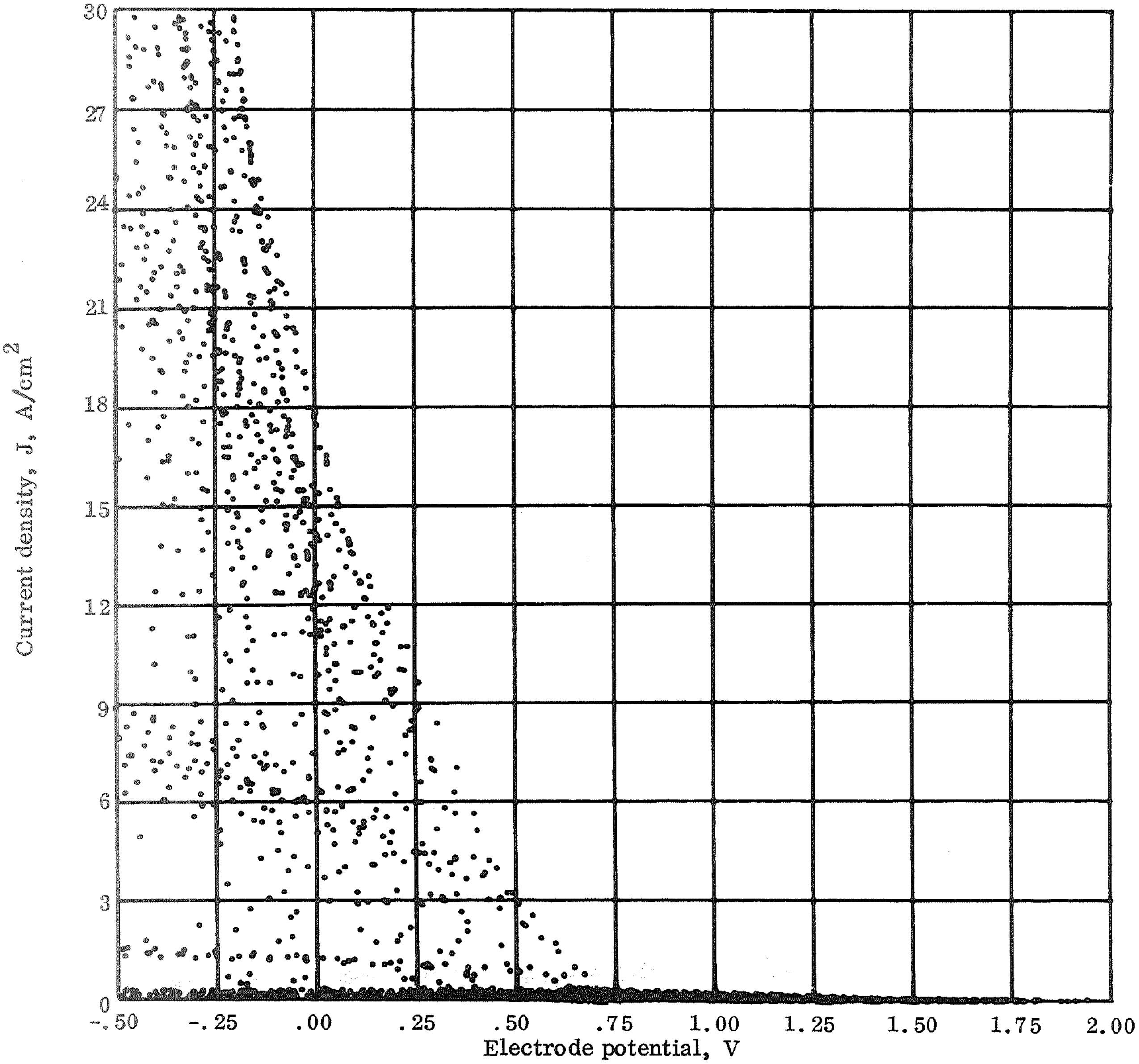

Figure 4. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1650 K. Collector temperature, 771 K to 1050 K; cesium reservoir temperature, 521 K to 651 K; interelectrode space, 0.254 mm (10 mils).

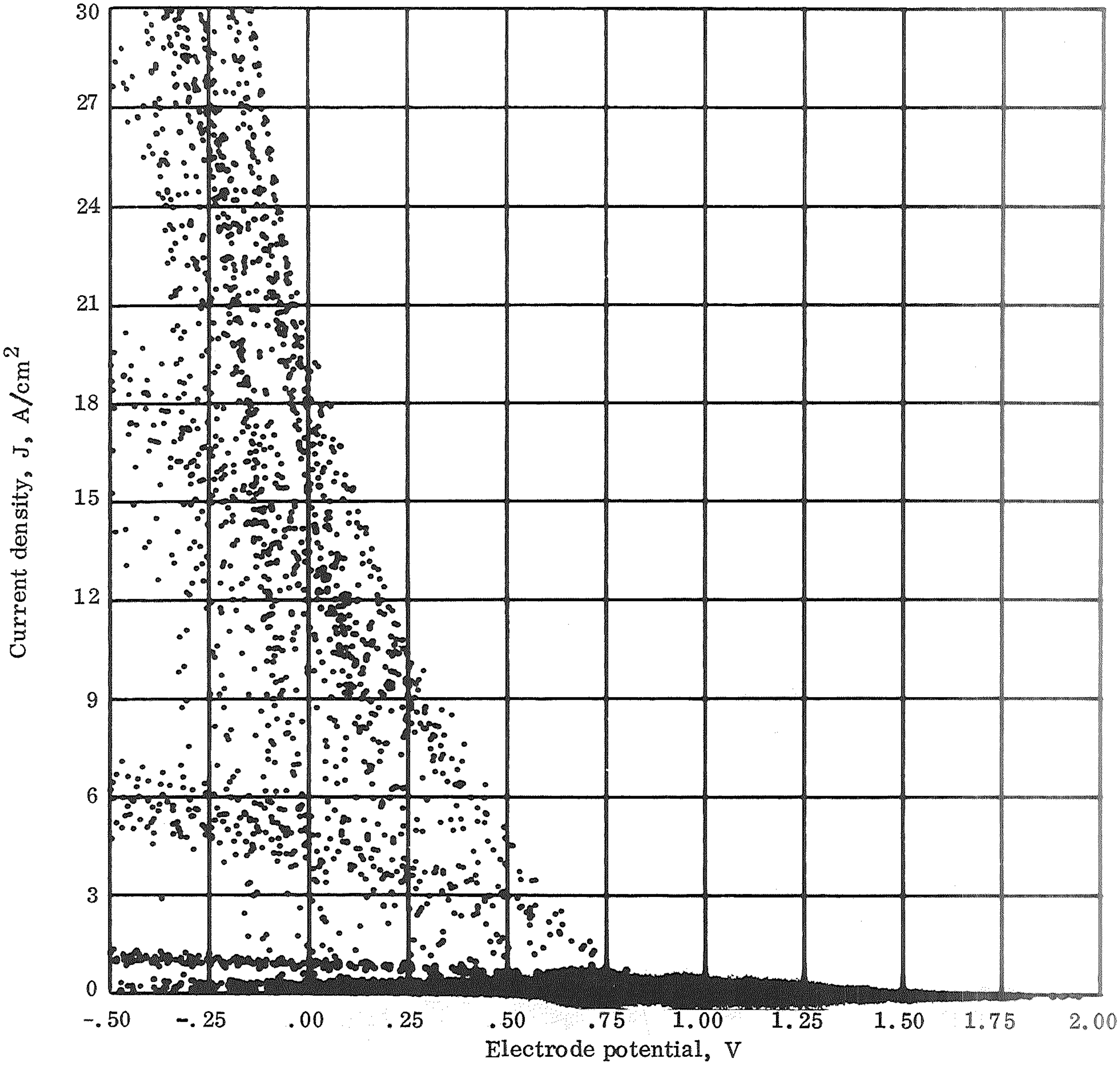

Figure 5. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1700 K. Collector temperature, 767 K to 1049 K; cesium reservoir temperature, 522 K to 651 K; interelectrode space, 0.254 mm (10 mils).

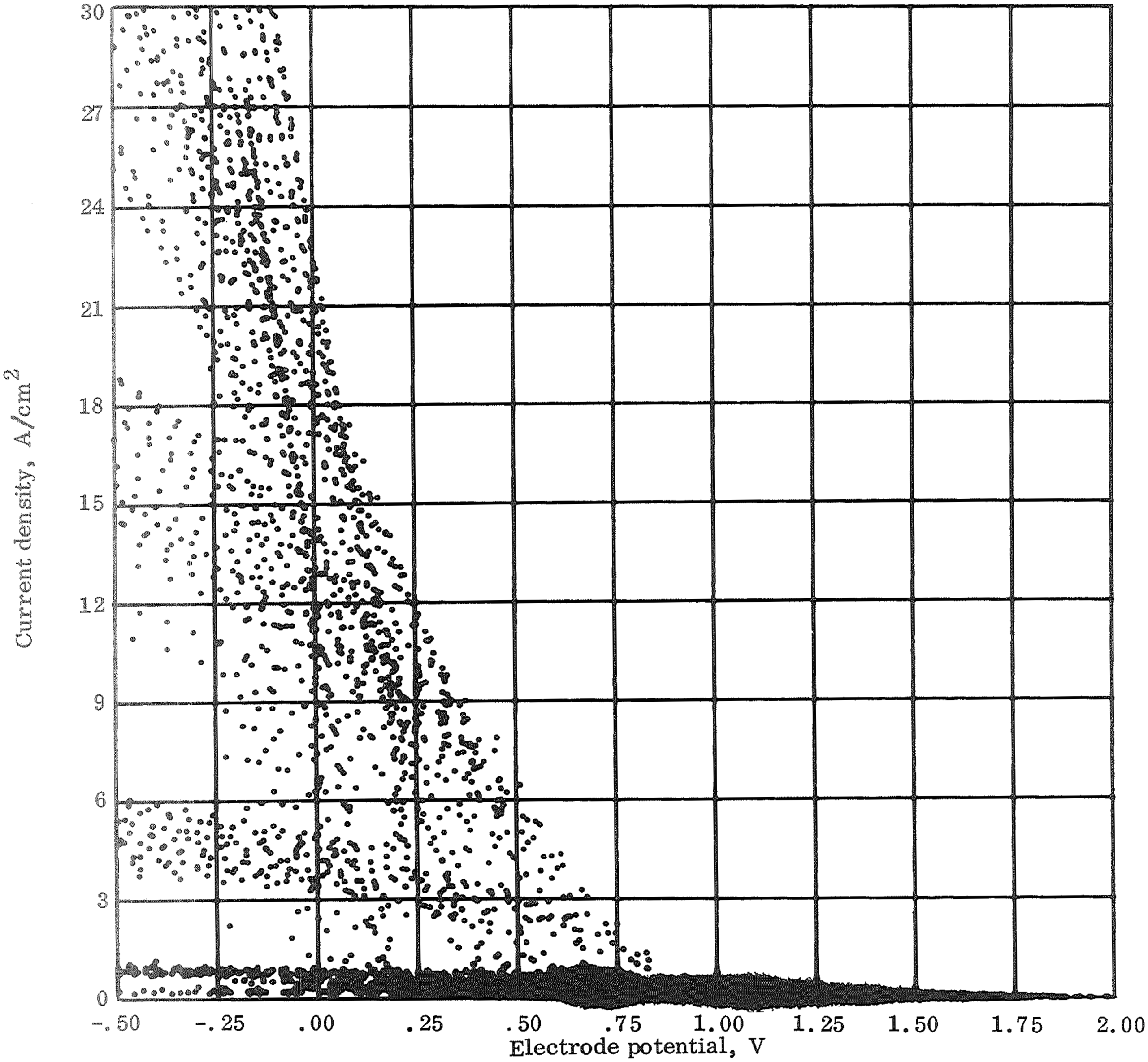

Figure 6. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1750 K. Collector temperature, 767 K to 1050 K; cesium reservoir temperature, 523 K to 651 K; interelectrode space, 0.254 mm (10 mils).

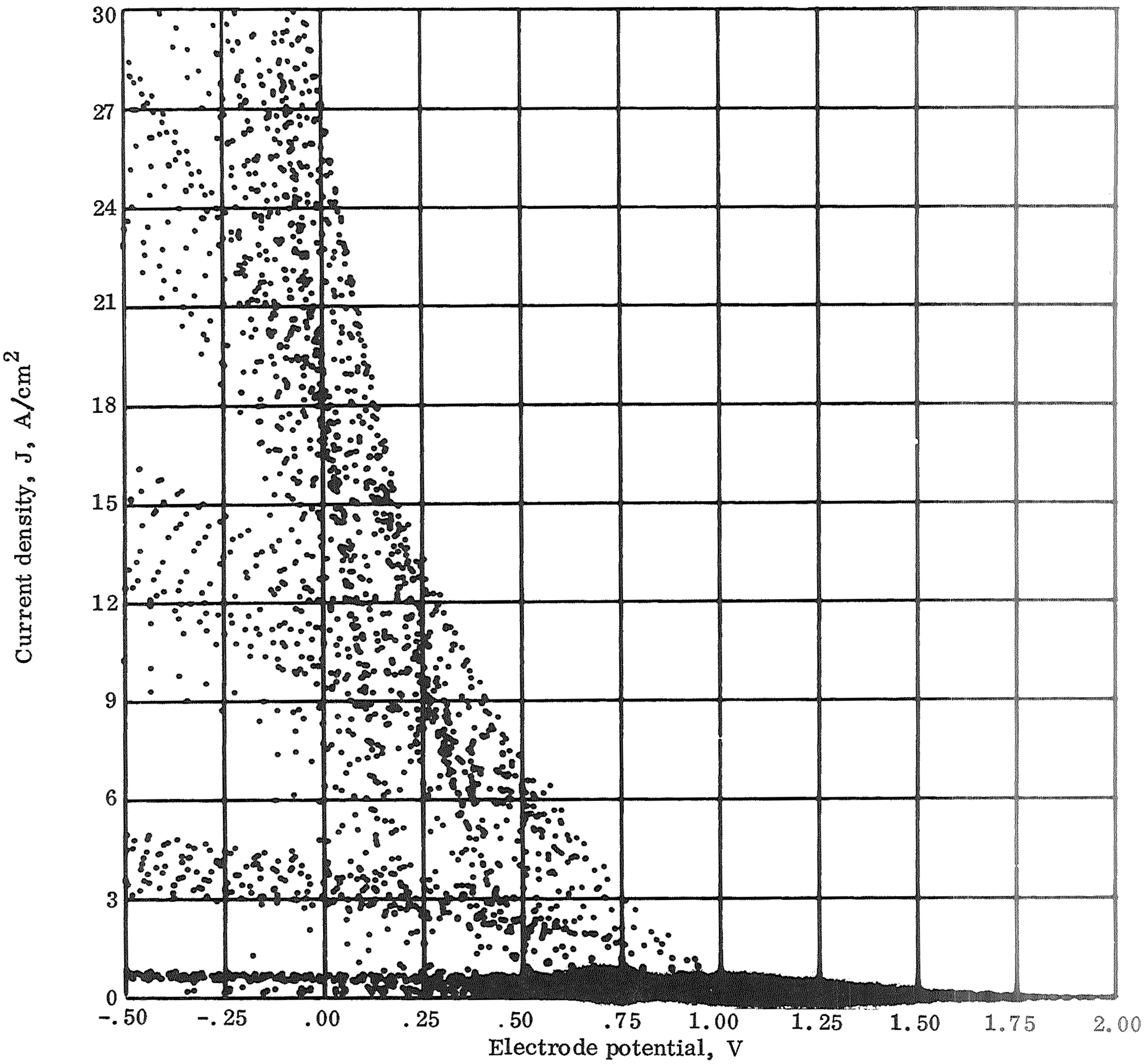

Figure 7. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1800 K. Collector temperature, 767 K to 1049 K; cesium reservoir temperature, 523 K to 651 K; interelectrode space, 0.254 mm (10 mils).

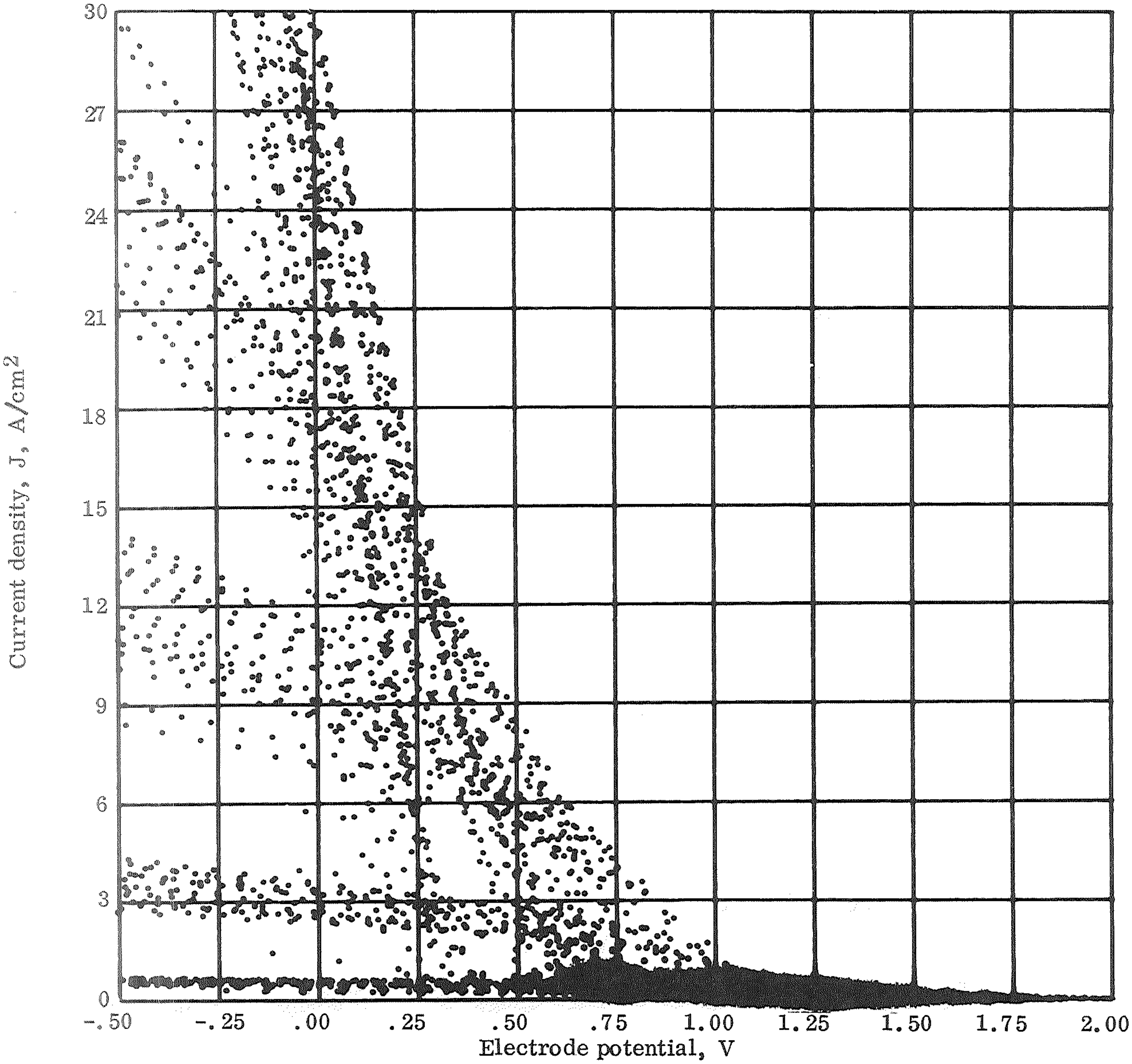

Figure 8. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1850 K. Collector temperature, 768 K to 1052 K; cesium reservoir temperature, 523 K to 651 K; interelectrode space, 0.254 mm (10 mils).

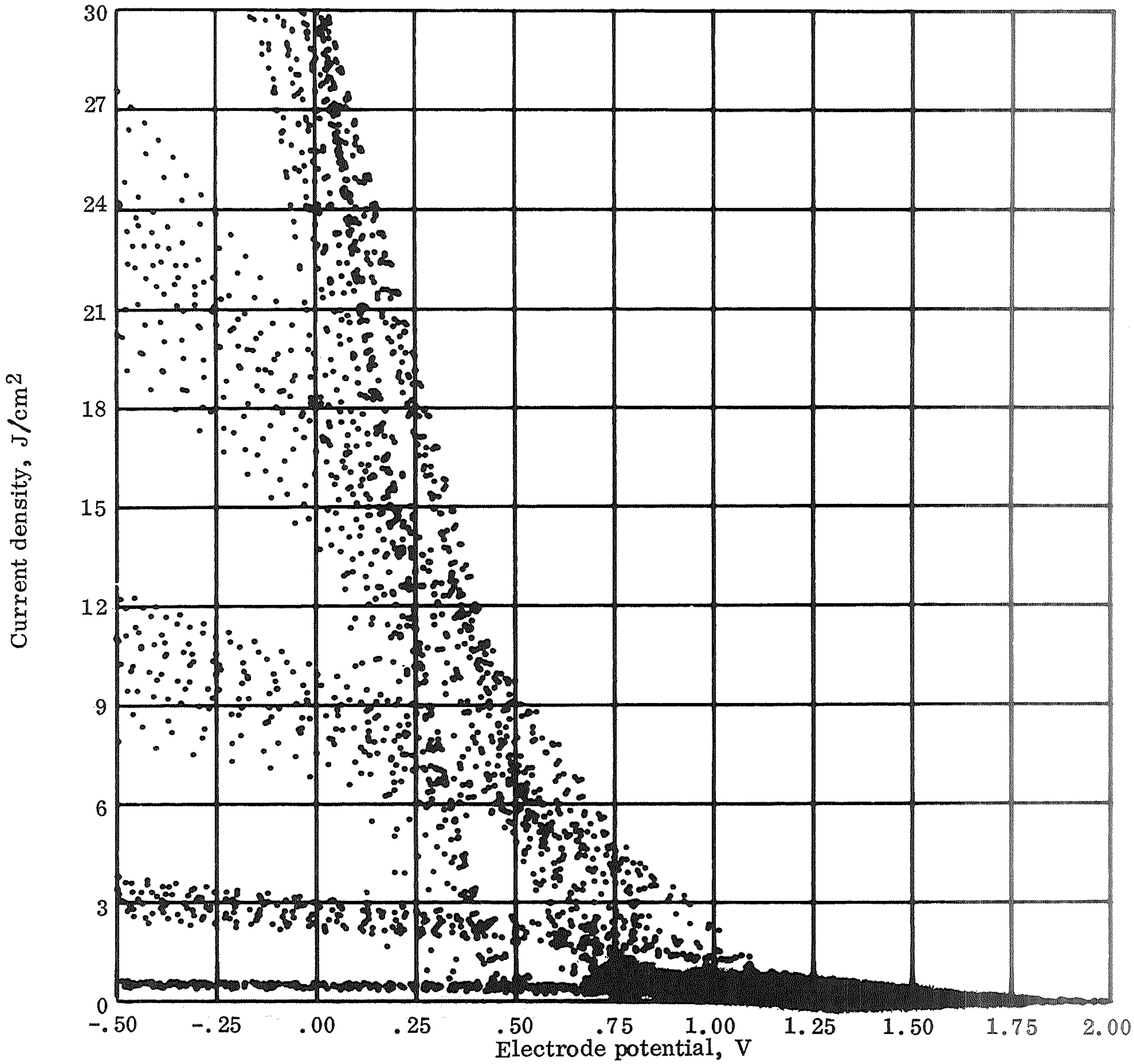

Figure 9. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1900 K. Collector temperature, 769 K to 1055 K; cesium reservoir temperature, 523 K to 651 K; interelectrode space, 0.254 mm (10 mils).

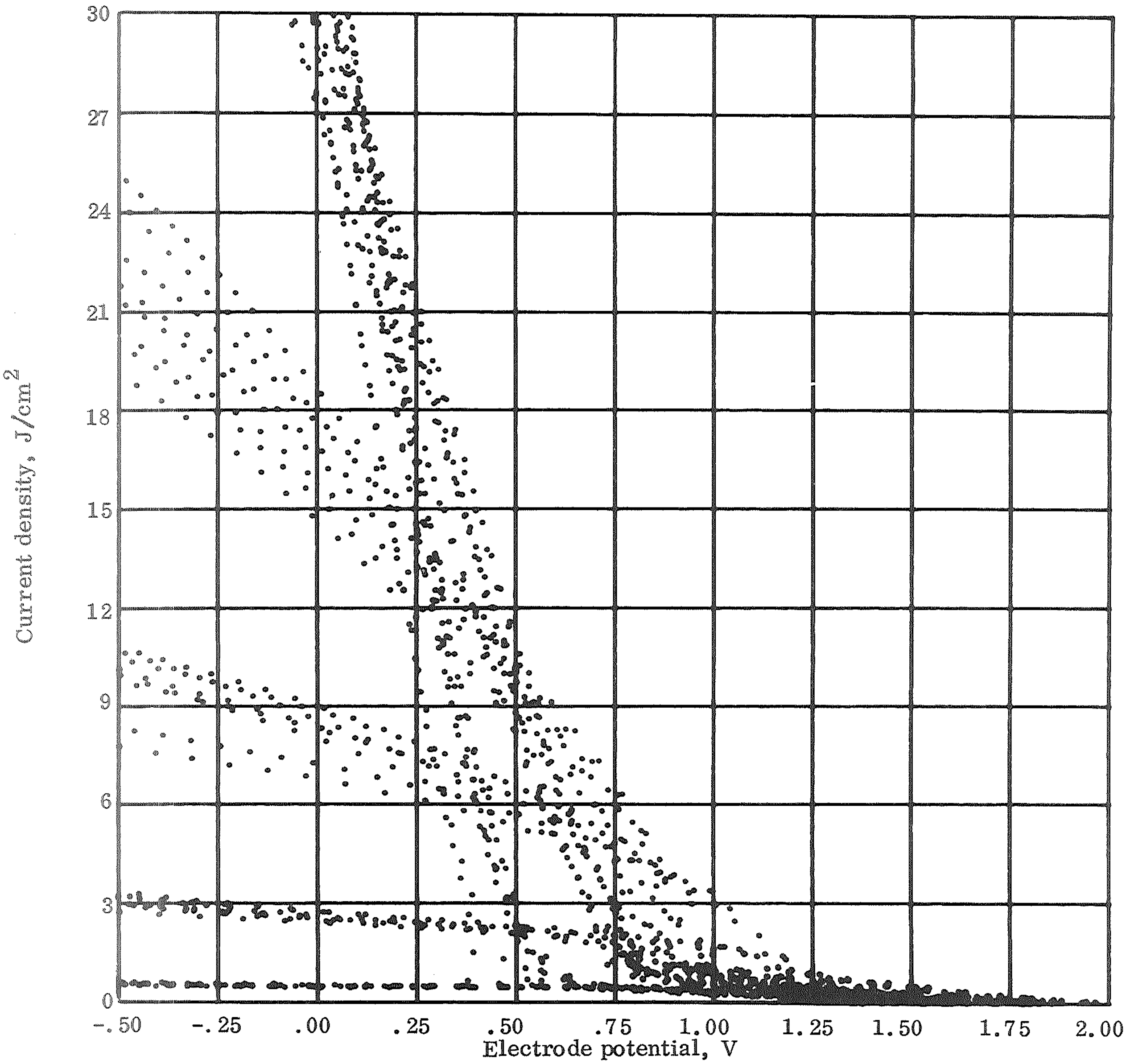

Figure 10. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 1950 K. Collector temperature, 773 K to 1057 K; cesium reservoir temperature, 523 K to 651 K; interelectrode space, 0.254 mm (10 mils).

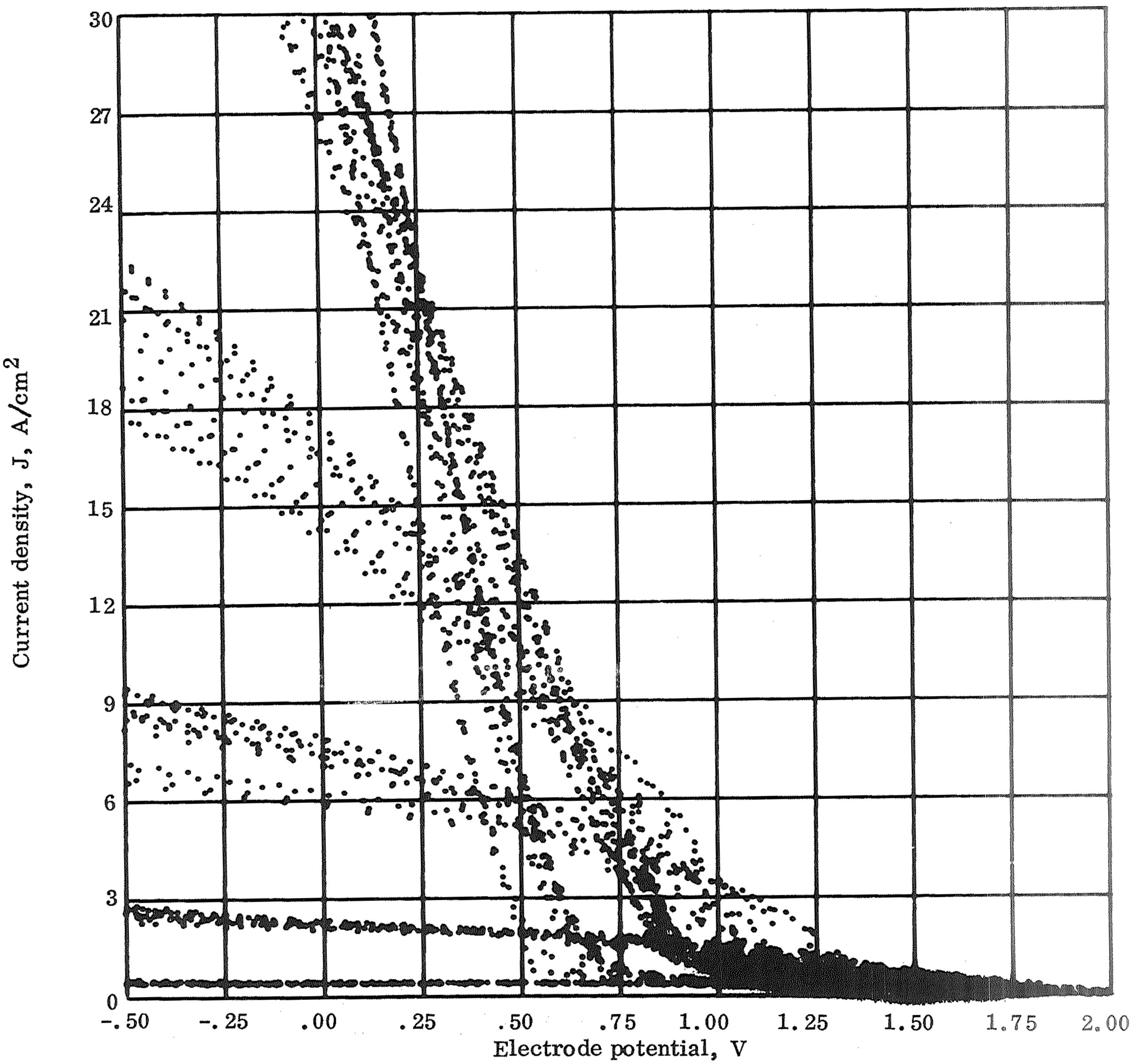

Figure 11. - Computer processed composite plot of current-density, voltage data at constant emitter temperature of 2000 K. Collector temperature, 771 K to 1055 K; cesium reservoir temperature, 523 K to 651 K; interelectrode space, 0.254 mm (10 mils).

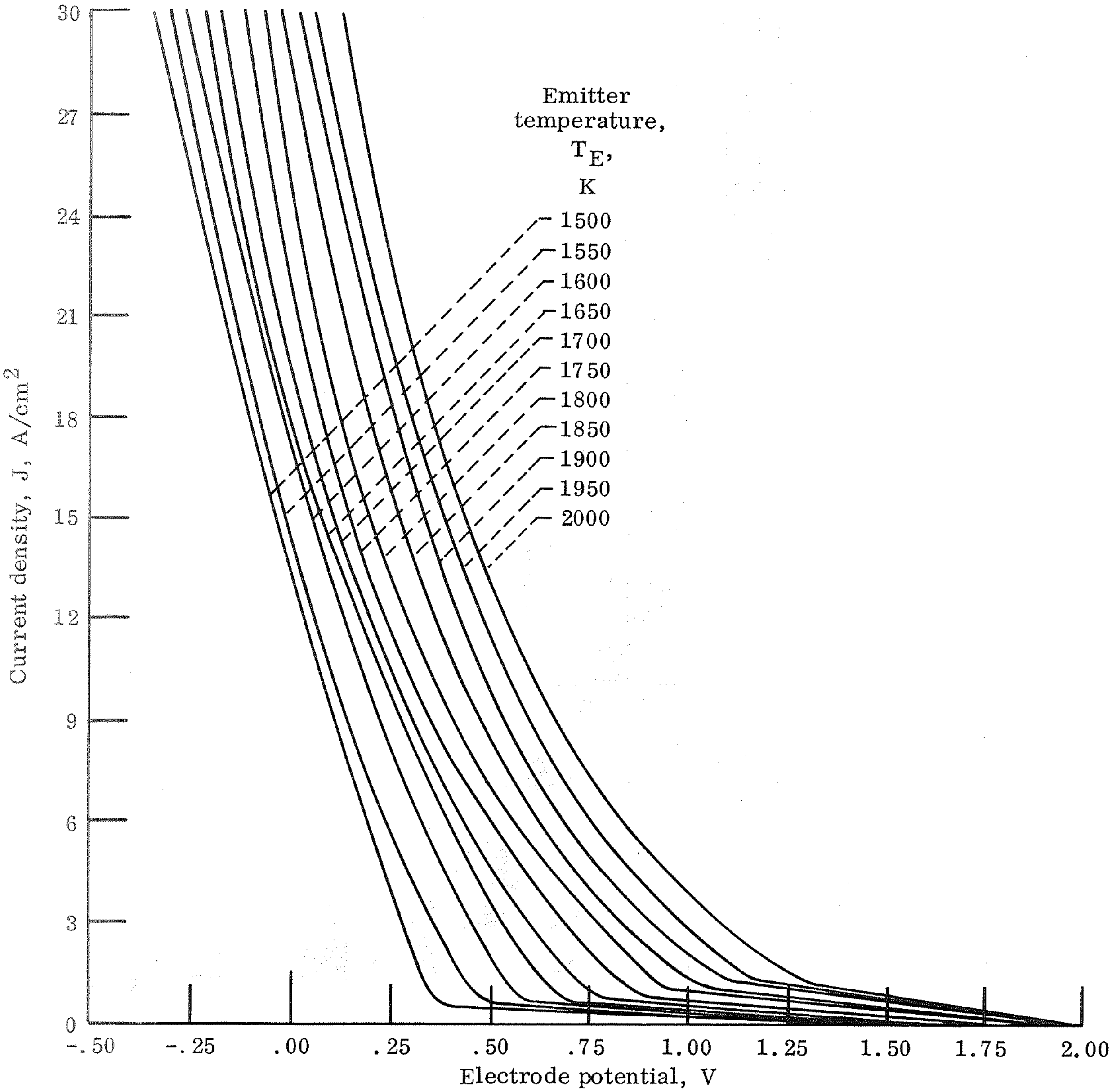

Figure 12. - Envelope curves for physically vapor-deposited-tungsten, niobium planar converter at various emitter temperatures.

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